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b. Applicant(s)	g. Disclaimer	l. Print Fig.	q. PTOL-85b
c. Continuing Data	h. Microfiche Appendix	m. Searched Column	r. Abstract
d. PCT	i. Title	n. PTO-270/328	s. Sheets/Figs
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SPECIFICATION

a. Page Missing
b. Text Continuity
c. Holes through Data
d. Other Missing Text
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g. Brief Description
h. Sequence Listing
i. Appendix
j. Amendments
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CLAIMS

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b. Improper Dependency
c. Duplicate Numbers
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E-5 (Rev. 10/01/02)

THREE-DIMENSIONAL PHOTONIC CRYSTAL WAVEGUIDE STRUCTURE AND METHOD

Cross-reference to related applications

This patent application is related to U.S. Patent Application No. 09/861,770 filed on May 22, 2001, and entitled "Method of forming three-dimensional photonic band structures in solid materials," which Patent Application is incorporated herein by reference. This patent application is also related to U.S. Patent Application No. 10/053003, co-filed with the present application on January 17, 2002, and entitled "Three-dimensional complete bandgap photonic crystal formed by crystal modification," which Patent Application is incorporated herein by reference.

Field of the Invention

The present invention pertains to waveguides, and in particular to waveguide structures and methods employing photonic crystals.

Background of the Invention

The wave nature of electrons and the periodic lattice of atoms give rise to allowed energy bands and forbidden energy gaps for electrons in a solid. The forbidden gaps arise from the destructive interference of electrons for certain wavelengths and directions. If a forbidden gap exists for all possible directions, it is referred to as a complete bandgap. A semiconductor has a complete bandgap between the valence and conduction bands.

The optical analogy is the photonic crystal, where a periodic lattice of contrasting dielectric structures (i.e., different indices of refraction) provides the periodic potential for light that atoms do for electrons. Photonic crystals can be thought of as extensions of diffraction gratings (i.e., a one-dimensional photonic crystal) or naturally occurring crystals used in X-ray crystallography. Light interacting with a

a desired wavelength (e.g., x-ray, ultraviolet, visible, infrared, microwave, etc.), the lattice constant a_0 should be a fraction of the desired wavelength. The wavelength and width of the photonic bandgap also depend on the filling ratio, which is the ratio of the volume of the voids in the unit cell to the total volume of the unit cell.

According to the teaching of the present invention, by properly selecting the lattice constant a_0 and the "atom" (i.e., void) shape and size, a variety of 3D photonic crystals and thus 3D photonic crystal waveguide structures can be produced for the wavelength region of interest. The lower bound of the photonic bandgap wavelength is determined mainly by the smallest lattice constant a_0 and voids that can be formed in the particular substrate.

Waveguide structure with modified 3D photonic crystal

As mentioned above, the 3D photonic crystal waveguide structure of the present invention requires the formation of a complete bandgap 3D photonic crystal. However, certain 3D photonic crystals formed with certain space group symmetries and voids of a given size and/or shape may not provide the necessary complete photonic bandgap at one filling ratio but may do so at another. Thus, the present invention includes a method of forming a waveguide structure using a 3D photonic crystal modified to form a complete bandgap. A technique for forming a modified 3D photonic crystal structure is described in U.S. Patent Application No. 10/053003, filed on Jan. 17, 2002 and entitled "Three-dimensional complete photonic bandgap crystal formed by crystal modification," which Patent Application is incorporated by reference herein.

Ho et al., in their article entitled "Existence of a photonic gap in periodic dielectric structures," *Phys. Rev. Lett.*, Vol. 65, No. 25, 17 Dec. 1990, pp. 3152-3155, which article is incorporated by reference herein, have calculated the photonic band structure of the diamond lattice for air spheres (i.e., spherical voids) of various sizes in a dielectric background. Ho et al. have identified the conditions under which a complete bandgap exists for a diamond lattice of spherical voids.

Figure 2 is adapted from the article by Ho (Figure 3(a) therein), and plots the "gap/mid-gap ratio" versus the filling ratio for air spheres formed in a solid substrate.